Bio-Waste Derived Carbon Electrode Materials for Supercapacitor Applications using different Electrolytes

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

by

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DECLARATION BY THE SCHOLAR

I hereby declare that the short synopsis entitled **Bio-Waste Derived Carbon Electrode Materials for Supercapacitor Applications using different Electrolytes** being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in the Department of **Sciences (Program-Physics)** under the School of Sciences of Manav Rachna University, Faridabad during the academic year **2025-26**.

It is the work that is expected to be carried out under the supervision of **Dr. Ananna Bardhan** and co-supervision of **Dr. Avnish Kumar Sisodiya** and **Prof. Dinesh Kumar Sharma**.

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This is to certify that, the short synopsis entitled **Bio-Waste Derived Carbon Electrode Materials for Supercapacitor Applications using different Electrolytes** is an original piece of work done by research scholar **Divya** under the supervision of **Dr. Ananna Bardhan** and co-supervision of **Dr. Avnish Kumar Sisodiya** and **Prof. Dinesh Kumar Sharma** for the degree of Doctor of Philosophy in the Department of Sciences(Program-Physics) under the School of Sciences of Manav Rachna University, Faridabad during the academic year **2025-26**.

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ABSTRACT

Improvements in energy efficiency in conversion and storage devices have been the need of the hour in today's society, and it has captured the attention of researchers globally. Electrochemical energy storage devices vis-à-vis batteries and electrochemical supercapacitors are important segments of storage devices. Recently, supercapacitors have gained global attention as a power source due to their high specific power and exceptional cycle life.

To boost the performance of supercapacitors serval efforts have been made by scientists worldwide by incorporating nanomaterials and nano-composites etc. On the other hand, different types of electrolytes, such as aqueous, organic electrolytes and polymer-based Electrolytes, including ionic liquids, etc. have been used as electrolytes to improve their performance.

In this work, we plan to undertake novel carbon materials as electrodes and different compositions of electrolytes for improved versions of supercapacitors. We will use mango seed to produce novel carbon materials for electrodes using carbonization and activation simultaneously in the furnace in a low oxygen atmosphere. After that synthesized material would be further treated and modified to get optimized material suitable as an electrode for a high-performance supercapacitor. Further, polymer-based electrolytes will also be prepared using the solution cast technique, it will be characterized using various physicochemical (FTIR, Raman, and BET etc.) and electrochemical techniques (Impedance spectroscopy, Cyclic voltammetry, leaner sweep voltammetry). Both these components (electrodes and electrolytes) would be employed in fabricated supercapacitor cell assembly. The study of performance parameters like specific capacitance, energy density, power density, cycle life etc. would also be carried out on these newly assembled cells.

Keywords: super-capacitor, electrode, electrolytes, energy

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1. Introduction

1.1 Supercapacitor

Given the evolving global demands, energy has become a central priority for leading nations and the scientific community. There is significant interest in advancing energy solutions and enriching more effective energy storage devices. Energy generated and gathered must be stored for household and diurnal need-based portable applications using devices like batteries and supercapacitors. The supercapacitors may lead to a revolutionary improvement in energy conversion. The supercapacitors have undergone significant progress over the past ten years and have surfaced with the potential to help address the global energy dilemma. The reversible electrostatic buildup of ions on the surface of porous carbon is the fundamental energy storage process of supercapacitors [1]. Current collectors, two active electrode materials, an electrolyte, and a separator are the primary parts of a supercapacitor. Supercapacitors are classified into various categories depending upon their materials and components used in fabrication. These various categories of supercapacitors are briefly discussed below.

Types of supercapacitors

Supercapacitors are typically divided into three categories based on how they store charge: hybrid supercapacitors, electric double-layer capacitors (EDLCs), and pseudo-capacitors [2]. EDLCs store charge electrostatically at the electrode-electrolyte While pseudo capacitors store charge through electrochemical Faradaic redox processes.

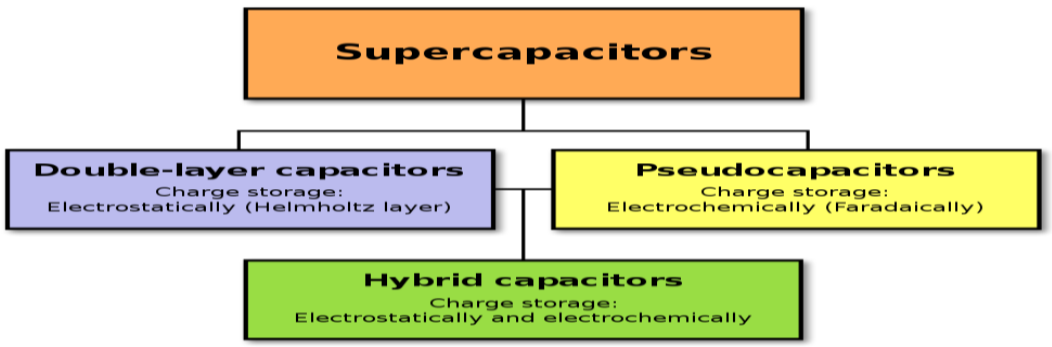

Fig.1: Types of electrochemical supercapacitor [3]

EDLCs offer high power density and excellent stability but have lower capacitance, while pseudo-capacitors exhibit the opposite characteristics. Notably, hybrid supercapacitor devices combine both EDLC and pseudo-capacitor electrode materials, leading to an extended operating potential window, higher energy densities, and increased capacitance [**4**].

i. Pseudo Capacitor

The pseudo capacitor is based on a mechanism where an Electrical energy is stored through the transfer of electron charges between the electrode and electrolyte, achieved via electro-sorption and redox (reduction-oxidation) reactions. pseudo capacitor is a type of electrochemical capacitor that works alongside an electric double-layer capacitor (EDLC) to form a hybrid system.

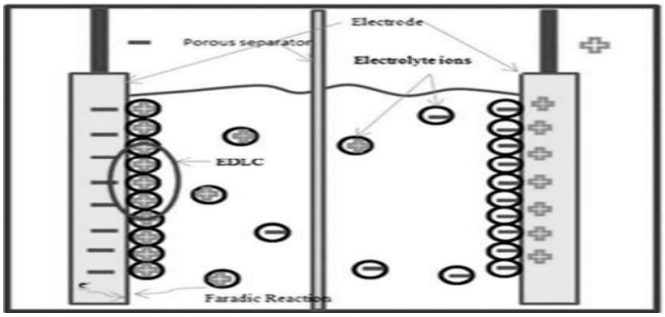

Fig.2: Pseudo supercapacitor [5]

ii. Hybrid Capacitor

The hybrid supercapacitor possesses a more working potential window, greater energy densities, and higher capacitances because of its structure, which includes both EDLC andpseudo-capacitor electrode materials [6]. Powerful electric motors andportable electronic devices belong to the applications in which the voltage range, energydensity, and power density eventually decide their use. Hybrid materials which include carbon and transition metal oxide (TMO) are showing significant potential for storage of energy use. Experiments and further studies are now underway on the hybrid and pseudo capacitors. They are not utilized in the community. Regarding hybrid and pseudo capacitors, although much work remains to be done, these devices

could meet energy demands if they become viable.

iii.Electric double-layer capacitor (EDLC)

A porous membrane covered in an electrolyte solution separates the two porous carbon electrodes (usually activated carbon) in direct contact with current collectors that make up an electric double-layer capacitor (EDLC). An equal number of positive cations at the electrode/electrolyte interface balance the electron accumulation on the negatively charged electrode caused by a voltage applied across the electrodes. At the same time, anions balance out the holes on the positively charged electrode.

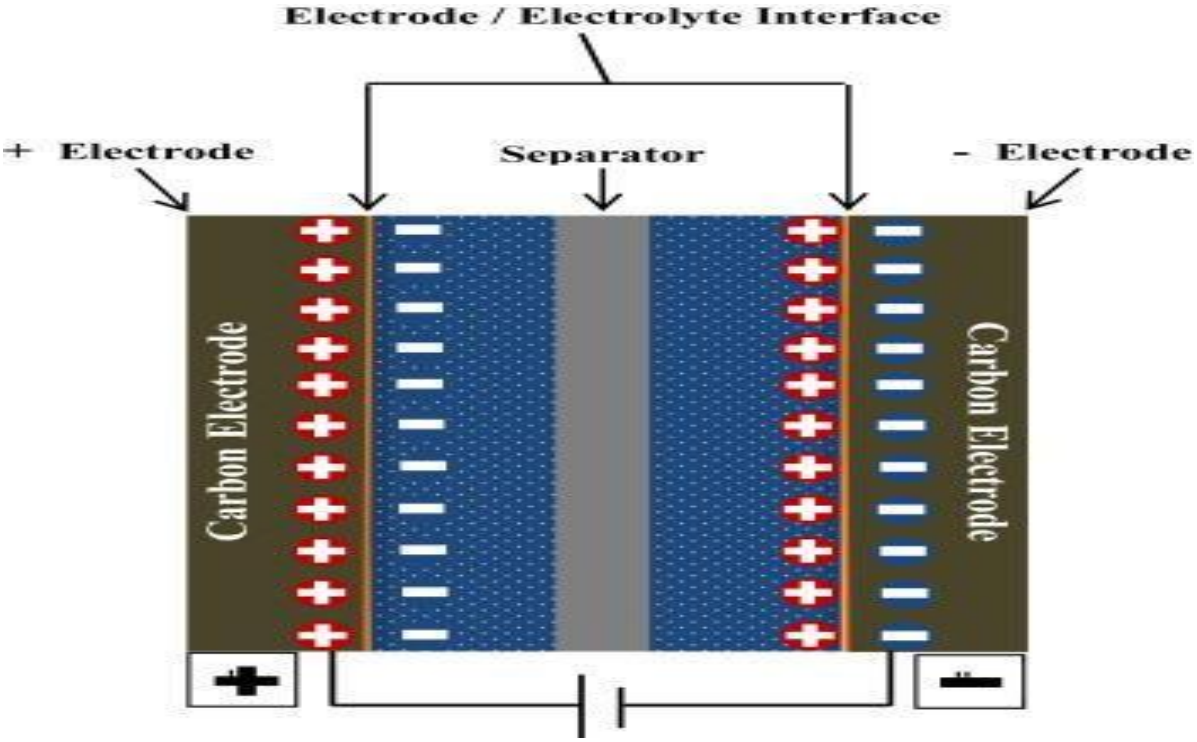

Fig.3: An EDLC supercapacitor with porous electrodes [**7**]

Lots of work is being carried out for the development of better-performing EDLC devices.In this proposal, we plan to work on EDLCs. Commercial EDLCs are available in the market but further they need to improve their performance are required to meet current energy demand. This improvement can be accomplished by way of manufacturing improved electrode and electrolyte materials. In this present proposal we plan to focus on new biomass waste carbon electrodes and a combination of polymer-based electrolytes.

The power output of supercapacitor is determined by the characteristics of each component, such

as the separator, electrodes, electrolytes, and current collectors, as well as how these parts are assembled, and constructed to form the cell [8]. Various types of active materials are used to make the electrodes. The wide range of carbonaceous materials are used for electrode materials. Because carbon precursor supplies are renewable and widely accessible, these electrodes are inexpensive [9]. The literature has reported on several carbon electrodes with varying topologies and porosities. Owing to their renewability, several biomasses have been tested as carbon materials for developing sustainable high-performance devices for supercapacitors. The components of a supercapacitor are given below:

a) Electrode

In supercapacitors, the electrodes are critical components that store and release electrical energy. The electrodes are typically made from high-surface-area materials to maximize energy storage. Because of its large surface area and affordable price, and good electrical conductivity activated carbon is the most commonly utilised material for supercapacitor electrodes. The electrodes are typically designed to have high porosity and surface area to facilitate the accumulation of electric charge and enhance the overall performance of the supercapacitor [10].

b) Electrolytes

The electrolyte is a component that allows the ions to pass between the two electrodes of supercapacitors, providing electrical energy to be stored and released. The electrolyte used in a supercapacitor has significant effects on its performance, energy density, and operating voltage. The common electrolyte types are

Aqueous Electrolytes:

Aqueous electrolytes are the water-based solutions. These having salts such as sulfuric acid (H_2SO_4) and potassium hydroxide (KOH). These substances having strong ionic conductivity and inexpensive. However, they have a smaller voltage window (usually 1-2 V), which restricts their energy density [11].

Organic Electrolytes:

These electrolytes depend on organic solvents like propylene carbonate (PC) or acetonitrile (AN) with dissolved salts (e.g., tetraethylammonium tetrafluoroborate, TEABF). They have broad

voltage window (up to 3.5-4 V) than aqueous electrolytes, which increased energy density but it is more costly and possibly harmful [12].

Ionic Liquids:

These electrolytes are liquid salts at room temperature, which include imidazolium and pyrrolidinium salts. Ionic liquids electrolytes have a broad voltage range (up to 4-5 V) and excellent stability, making them useful for high-performance supercapacitors. However, they are slightly more costly and have reduced ionic conductivity than aqueous or organic electrolytes [13].

The electrolyte helps facilitate the charge and discharge process by allowing ions to move between the electrodes during operation, directly influencing the supercapacitor's efficiency, energy density, and power output.

c) Separator

The separator is one of the most important parts of the supercapacitor. Rubber, aqua gel, and polyolefins are just a few of the materials that have been used to create separators [14].

The following characteristics are required of these separators:

- be thin and providing electrical insulation to prevent an electrode short circuit.
- be stable electrochemically in the electrolytes and have strong dielectric properties.
- Furthermore, favours high ionic mobility between the electrode surface and the electrolyte.
- Separators should be cost-effective, thin, capable of high electrolyte uptake, and thermally stable [15].

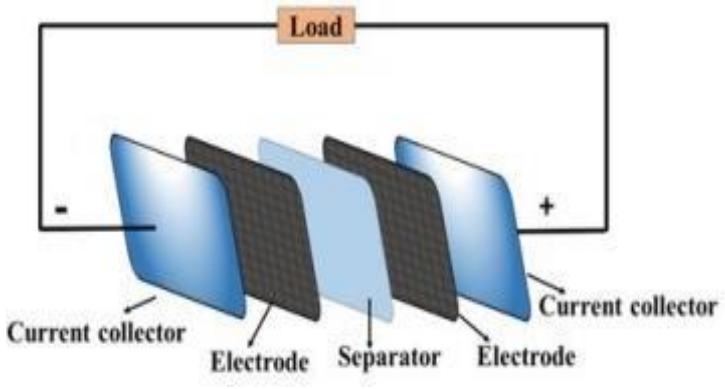

Fig.4: - Basic components of a supercapacitor [15]

2. Literature Review

In the last two decades, there has been a great surge in the number of publications on supercapacitors worldwide. Recently, a serious effort has been made by various researchers. A few of them are reviewed in this section.

Alagar *et al.* 2020 produced ultra-stable nano/sub microspheres of Mn1-xNixCO3 (x-0, 0.20, 0.25, and 0.30) through co-precipitation technique, and XRD, FT-IR, and XPS tests were performed to confirm the Mn1-xNixCO3. TEM and scanning electron microscopy(SEM) analysis have been employed to investigate their morphology. The electrode with the highest specific capacitance, Mn0.75Ni0.25CO3, was 364 F g^{-1} at 1 A g^{-1}. as well as the greatest capacity stability (96% after 7500 cycles at 5 A g^{-1}) among all three Mn1-xNixCO3 electrodes. An energy density of 25 Whkg^{-1} and a large specific capacity of 46 F g^{-1} at a power density of 499 W kg^{-1} were additionally demonstrated by the developed solid-state asymmetric supercapacitor using graphene nanosheets and Mn0.75Ni0.25CO3, along with a high-capacity retention of 87.7% after 7500 cycles. The electrochemical activity and internal conductivity of MnCO3 succeeding Mn1-xNixCO3 are primarily responsible for the boosted electrochemical performances [16].

Ding *et* al. 2020 developed the use of anthracite activated carbon (AAC) and activated millet straw carbon (MAC) for supercapacitors (SC) by thermal changing them to a mass ratio of 5:1 (KOH: C). The MAC electrode's area of CVs when performing the cyclic voltammetry test is greater than AAC's, especially when measured at 100 and 200 mV/s. In the EIS test, the AAC electrode's ESR (0.28Ω) is greater than 6.5 times that of the MAC electrode (0.043Ω). The GCD measurements show the activated biochar electrode'sspecific capacitance is greater than the AAC

electrode in all of the cases. The specific capacitance of the MAC electrode is 144 F/g at a current density of 0.2 A/g, compared toonly 85.2 F/g for the AAC electrode. [17].

TU *et al. 2023* Developed successfully a supercapacitor at high temperature carbonization and KOH activation using American ginseng waste residue (AGWR) as a biowaste waste. Using X-ray diffraction (XRD) for the crystallographic structure and X- ray photoelectron spectroscopy (XPS) using for surface composition. The specific surfacearea is found 2187 m2 /g and the specific capacitance value is 268 F/g at a current density of 0.1 A/g, with 6M of electrolytesAdditionally, after 10,000 cycles, the developed supercapacitor retained 97.47% of its initial capacitance. [18].

Rui *et al.* 2020 increased the supercapacitor's conductivity through electrophoretic ionic deposition of carbon electrodes adjusted by decreased graphene oxide content. The various amounts of graphene oxide solutions can be applied to modify the amount of lessgraphene oxide loading, or the reduction potential may vary to achieve different reduction states and thus modify the conductivity. After decreased graphene oxidecoatings, the specific capacitance of 167 F g^{-1} is obtained, This amounts to 4.3 times more than the same quantity of biochar without graphene oxide reduction. At current densities ranging from 0.5 to 3.0 A g^{-1}, biochar electrodes improved by reduced graphene oxide indicate a high-rate ability retention of close to 90 per cent. Moreover, under 5.0 Ag^{-1}, no decrease in efficiency has been observed after 10,000 charging as well as recharging cycles [19].

Edberg *et al.* 2019 developed the supercapacitor using renewable and organic elements, such as nitrocellulose, conducting polymers, and the organic pigment alizarin colour. The improvements in the storage of energy have been attributed to the dye molecule, which was previously isolated from the plant Rubia tinctorum's roots. The conductive polymer promotes bulk charge movements through the composite electrode. The conductive polymer organizes itself into the physically strong and nonporous network offered by the forest-based nanocellulose element. The electrical and electrochemical characteristics of the material compositions have been examined, and prototype redox-enhanced supercapacitor devices with a specific capacitance close to 400 F g^{-1} and operational stability for >1000 cycles have been proven. Thisnovel type of supercapacitor, which is mainly derived from plant-based elements, is an important step toward [20].

Mangisetti *et* al. 2019 hired an environmentally friendly approach for producing three individual

carbon microstructures for completely biodegradable supercapacitors with flexibility and their ability to function with various electrolytes using one type of biowaste bombax malabaricum. Three unique parts of a biowaste material, Bombax malabaricum are used for the manufacture of N-doped carbon microflakes (N-CMF), three-dimensional honeycomb-like porous carbon (N-HPC), and two-dimensional wrinkled few-layered porous graphene nanosheets (N-HGNSs). To the best of our understanding, the high specific capacitance (Cp) values obtained for N-HGNS, N-HPC, and current density of 1.5 A g^{-1} in 1 M H_2SO_4, N-CMF electrode materials—523, 458, and 363 F g^{-1} respectively—have one of the highest recorded high-rate capacities of approximately 82% at 30 A g^{-1} for N-doped carbon-based materials made from biowaste [21].

Subramani Kaipannan and Sathish Marappan 2019 hydrated Ni $(OH)_2$. They reported here the fabrication of symmetric supercapacitors containing Ni $(OH)_2$ nanosheets acting as the positive electrode and activated carbon serving as the negative electrode in an aqueous electrolyte. A steady device voltage of 9.6 V has been shown by a collection of asymmetric supercapacitors connected in series with each other, that additionally generated a high energy and power retention of 30 mWh and 1632 mW, respectively. The device that has been developed shows exceptional electrochemical stability and exhibits a high 81% initial capacitance retention after over 100,000 cycles of charge -discharge at a high 500 mA charging current. The nickel hexacyanoferrate complex was chemically split down to generate the positive electrode's material, Ni (OH)2 nanosheets. a hierarchical nanosheets are created by the chemical synthesis of Ni(OH)2. -SEM and HR-TEM studies show that hierarchical nanosheets having arbitrary orientations develop following the chemical manufacturing of Ni (OH)2. Orange peel waste was utilized to generate activated porous carbon (OPAA-700), the negative electrode. Ni $(OH)_2$ nanosheets and OPAA-700 were examined to evaluate their electrochemical capabilities; at a current density of 2 A/g, the first material displayed a large specific capacitance of 311 F/g and the latter, a high specific capacity of 1126 C/g. At a high current density of 32 A/g, Ni $(OH)_2$ nanosheets achieved excellent capacitance retention of 96% having good rate performance [22].

Mohit, Yadav & Hashmi 2022 produced a supercapacitor by forming porous activated carbon from sugarcane luggage bio-waste that has been pre-treated with hydrothermal and solvent (ethanol) soaking. The ACs have been electrochemically tested and are chemically and physically activated using a flexible quasi-solid-state gel polymer electrolyte that contains 0.5M sodium triflate (NaTf) in an ionic liquid 1- ethyl-3-methylimidazolium trifluoro methane-sulfonate (EMITf) integrated in poly (vinylidene fluoride-hexafluoropropylene) (PVdF-HFP).

They have shown excellent electrochemical stability (~4.7 V vs Ag/Ag+) and good ionic conductivity (~8.5 mS cm^{-1}). ESB electrodes display particular capacitance (~193 F g^{-1}), specific energy (~32 Wh kg^{-1}), and maximal power density (~55 kW kg^{-1}). Comparing the ESB-based supercapacitors to other AC electrodes, they likewise show a comparatively high rate [23]. Mohit and Hashmi (2023) created a supercapacitor that was made up of an ionic liquid (IL)-incorporated electrolyte (1-ethyl-3-methylimidazolium trifluoroethane sulfonate (EMITf)/Na-trifluoromethane sulfonate (NaTf) and a biodegradable polymer poly-ε-caprolactone (PCL) that was activated with organic liquid electrolyte (EC/PC)/NaClO4). Electrical double-layer capacitors (EDLCs) and quasi-solid-state carbon supercapacitors are manufactured. from symmetrical activated carbon (AC) electrodes, which are separated by PPE films and made from waste biomass, such as sugarcane bagasse. The supercapacitor with IL-incorporated PPE has higher specific energy (~34 Wh kg^{-1}) and specific capacitance (~170 F g^{-1}) compared to organic solvent-based PPEs (~130 F g^{-1} and ~24 Wh kg^{-1}, respectively). Longer-lasting light from LEDs (35-50 mW) demonstrates significant energy storage in supercapacitors. With an initial capacitance fading of roughly 15%, the device demonstrates steady performance for up to 10,000 charge-discharge cycles [24].

3. Description of Broad Area

The topic " **Bio-Waste Derived Carbon Electrode Materials for SupercapacitorApplications using different Electrolytes** " explores the utilization of bio-waste materialsto produce activated carbon, which serves as an electrode material in supercapacitors. Activated carbon, known for its high surface area and porosity, is a critical component insupercapacitors, which are energy storage devices offering rapid charge/discharge cycles and high-power density.

Bio-waste, such as agricultural residues, food waste, or other organic by-products, is an eco-friendly and cost-effective feedstock for activated carbon production. By converting these waste materials into activated carbon, the process not only recycles waste but alsocreates a valuable material for energy storage applications. Different electrolytes, such as aqueous solutions (e.g., sulfuric acid) or organic electrolytes (e.g., ionic liquids), can influence the performance of supercapacitors. The choice of electrolyte affects the capacitance, energy

density, and operating voltage of the supercapacitor. Research in this area focuses on optimizing the properties of activated carbon derived from various bio-wastes and testing them with different electrolytes to enhance the efficiency and sustainability of supercapacitors. This approach aims to improve energy storage solutions while addressing environmental and economic concerns associated with waste management.

4. Objectives of the research

1. To synthesize the carbon materials for supercapacitor electrodes using bio-waste materials by different methods.
2. Optimization and characterization of electrodes and electrolytes using different physicochemical techniques and methods.
3. Comparative electrochemical performance studies of the synthesized supercapacitors with the supercapacitors designed with commercial electrodes and electrolytes.
4. Investigate strategies to enhance the electrochemical performance of supercapacitors.

5. Methodology

5.1: Synthesis of supercapacitor electrode by carbon from bio-waste

The waste biomass mango-seeds bagasse will be first dried in a vacuum at ~110°C. This dried biomass will be crushed into fine powder by using a grinder. From the powder, biochar will be made. This fine powder will be put into alumina boats, and thereafter, transferred to a muffle furnace. The furnace will be heated at 5°C/min from room temperature to around 500°C. After reaching ~500°C , the furnace will remain held there for 2 hours. Then it will be allowed to cool naturally to room temperature to collect the biochar. This biochar will next be combined with a nitrogen-containing substance (urea) at a suitable ratio to achieve nitrogen doping. This mixture will be kept in an oven at 80°C for 8 hours. This doped carbon will be washed with an HCl solution to remove harmful ionic substances. Further, it will be washed with DI water. Finally, the doped carbon will be dried in a vacuum oven at ~110°C overnight, then powdered with the help of a mortar and pestle.

5.2 Preparation of Electrodes

The electrode will make by carefully combining activated charcoal, graphite powder, and binder PVA in acetone in a 75:15:10 ratio using a mortar and pestle. Using a spin coater (Apex Instruments, India), this slurry was applied to the flexible graphite sheet. On the graphite sheet, the carbon electrode's thickness was maintained at about 200 μm. The electrodes utilized to create the EDLCs had an area of about 2 cm and a mass of around 4 mg cm^{-2} of carbon composite. Before being used to create EDLCs, the prepared electrodes were vacuum-dried for an entire night at 100°C.

5.3 Synthesis of polymer electrolytes

Salts like $MnSO_4$, $ZnSO_4$, Na_2SO_4, and $MgNO_3$ as well as polymers like PVdF-HFP, PEO, PMMA, PVA, and PVP, among others, will be purchased from reputable companies. Before usage, the salt and ionic liquid will be vacuum-dried for approximately 12 hours at 100 °C. the polymer electrolyte films will be obtained. First, an ionic liquid will be used to make the liquid electrolyte solution. Acetone or another solvent unique to a given polymer will dissolve the polymer in it independently. he different ratios of liquid electrolyte and polymer solution will then be thoroughly mixed at room temperature using a magnetic stirrer for 4-5 hours. The mixtures will then be placed in glass Petri plates, allowing the common solvent to gradually evaporate. Finally, dimensionally stable free-standing transparent thick films of gel polymer electrolytes were created. Figure 5 displays an example of a gel polymer electrolyte (film) in general appearance. For comparison, the same method was used to make blends with varied polymer and ionic liquid/organic solvent weight ratios. These mixes were discovered in the form of dimensionally stable freestanding transparent thick films.

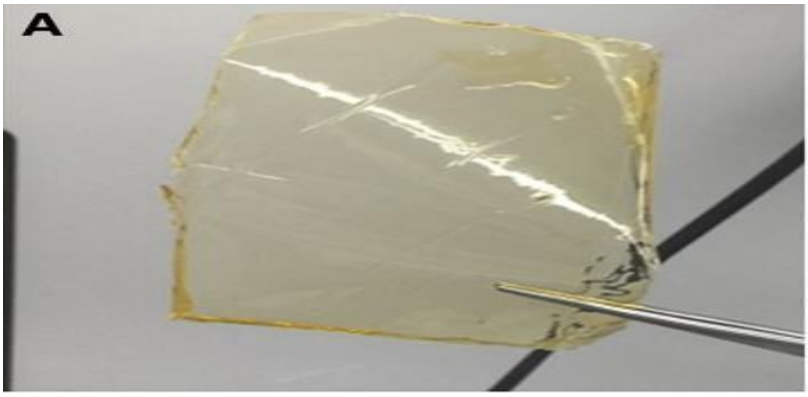

Fig.5: - Gel polymer transparent thick film [25]

5.4Fabrication of EDLC Cells.

Two methods will be used to construct EDLC cells: (i) The first step involves placing the free-standing gel electrolyte film piece on one electrode surface and covering it with the second symmetrical electrode (Figure 6a). (ii) A second approach will be used, in which the gel polymer electrolyte's acetone solution will spin-coat the electrode surface before allowing the acetone to evaporate. To create the entire cell, the two of these systems will be placed on top of one another and gently compressed (Figure 6b). A significant percentage of the electrodes' pores remain unused because they cannot reach the electrolyte film to create capacitive connections, as seen in Figure 6a.

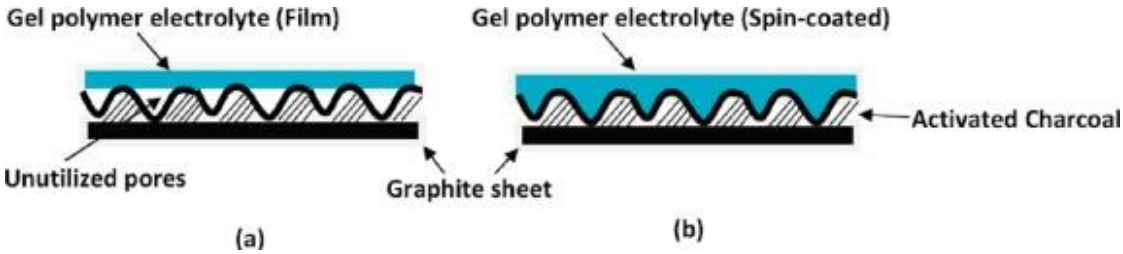

Fig.6: A diagram of two EDLC manufacturing processes using (a) thick-film gel polymer electrolyte and (b) spin-coated gel electrolyte [26].

As is the case in the spin coating process, the electrolyte fills in the pores of carbon electrodes to a greater extent, and the electrode's increased surface area is used to generate interfacial connections between the electrode and the gel electrolyte after acetone evaporation. EDLC cells were built with several gel polymer electrolytes and an activated charcoal (AC) electrode.

5.5 Characterization of Materials and Cells

5.5.1. Characterization of Materials

FTIR, XRD, BET, XPS, RAMAN etc. techniques are used for the characterization of materials.

Fourier Transform Infrared (FTIR)

This technique is used to analyse the chemical composition and functional group presentin the materials.

X-ray diffraction (XRD)

It provides information about the material structure and phase composition.

Raman

It studies the carbon relative micro and atomic structural information of activated carbon.

Brunner, Emmett- Teller (BET)

BET analysis provides information on the material's total specific surface area, the surface area of micro, miso, and macropores, as well as the pore size distribution and average pore size. In the N_2 adsorption/ desorption experiment, a surface area and pore size analyzer (Micromeritics) will be performed to determine the electrode materials' specific surface area and other porosity aspects.

Scanning Electron Microscopy (SEM)

The surface morphology and structural imaging of the electrode and electrolyte materials will be conducted. The surface morphology and structural imaging of electrode and electrolyte materials will be conducted. Complex -impedance measurements on the cell with a frequency range ranging from 1 Hz to 100 kHz with a signal level of 20 mV will yield the electrical conductivity of the polymer sheets (SS stands for stainless steel).

5.5.2. Characterization OF Cell

Impedance Analysis

Several electrochemical methods, including galvanostatic charge-discharge techniques, cyclic voltammetry, and AC impedance spectroscopy, will be used to analyze the EDLCs. The LCR meter will be utilized to do the impedance measurements. Using the formula

$$C = \frac{1}{WZ''}$$

where Z" is the imaginary fraction of the total complex impedance Z and ω is the angular frequency. By multiplying the total cell capacitance by two and dividing the result by the mass of

the single electrode material, the single electrode-specific capacitance values will be calculated [27].

Cyclic voltammetry

With the aid of an electrochemical analyzer, it will be carried out. The following relation was used to evaluate the capacitance values:

$$C = \frac{I}{S}$$

where s is the scan rate (ΔV/Δt) and where is the current [28].

Galvanic charge-discharge (GCD)

A properties at constant currents. Using the relation, the discharge capacitance C charge-discharge unit (model BT2000, Arbin Instrument) will be used to assess the capacitor cells charge-discharge will be calculated from the linear portion of the discharge curves.

$$C_d = \frac{I\Delta t}{\Delta V}$$

where Δt is the time interval for the voltage shift of ΔV and I is the constant current [29]

Expected outcomes of the research

In this work it is expected to yield several significant outcomes:

- Identification of optimal conditions for producing carbon from bio-wastes that maximize its surface area, porosity, and electrical conductivity. This would lead to improved performance of supercapacitors, such as higher specific capacitance, greater energy density, and better power density.
- By testing different electrolytes, the research will provide insights into how each electrolyte affects the performance of supercapacitors with activated carbonelectrodes. This could reveal which electrolytes offer the best balance of high voltage stability, wide operating temperature range, and efficiency in energy storage.
- The research will demonstrate the feasibility of using bio-waste as a sustainable and low-cost precursor for activated carbon. This could make supercapacitor technology more environmentally friendly and economically viable.

Overall, the expected outcomes aim to advance the field of energy storage by providing sustainable, high-performance materials and optimized electrolyte systems for supercapacitors.

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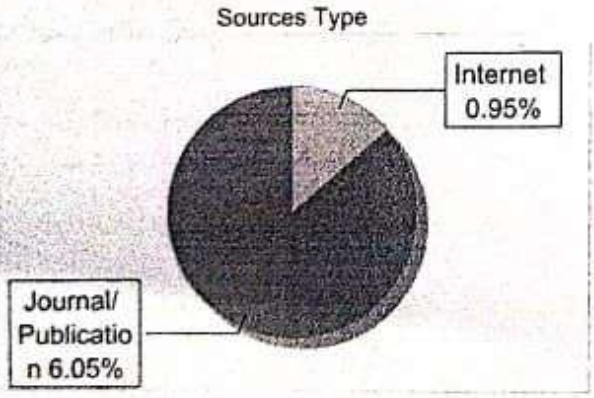

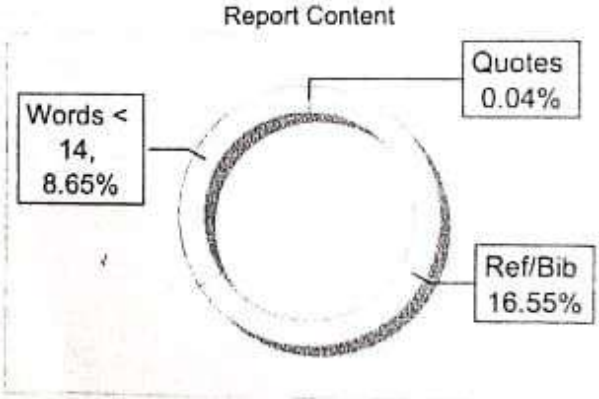

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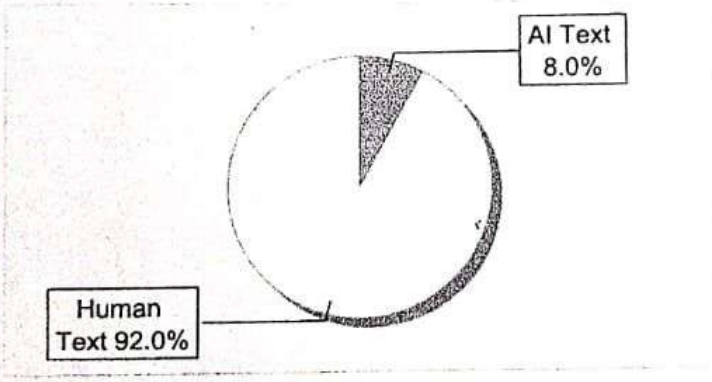

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